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UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

R-CAL
Investigative Program

THE WORK OF THE

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION

1936-1937

A Condensed Summary

of the Station's Annual Report and Plan

With Helpful Collateral Information

Prepared by

The California Forest and Range Experiment Station

1937

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R-CAL
Investigative Program July 20, 1937

THE WORK OF THE CALIFORNIA FOREST AND RANGE EXPERIMENT STATION 1936-1937

The area of the California Station's responsibility is that of National Forest Region 5, including the State of California, plus a strip of Nevada of 9 or 10 million acres. Net National Forest acreages within these two areas as of December 31, 1936 are: California, 19,259,626 acres, Nevada, 541,891.

The approximately 100-million-acre total area of California may be divided roughly into the following classes:

Topographic Classes	Millions of acres	Land Use Classes	Millions of acres
Valleys and lowlands	35	Agriculture (present and potential, irrigated and dry)	20
Foothills, up to 2500 ft. elevation	20	Timber land	20
Mountains, comm'l timber 2500-6000 ft.	30	Watershed and range land	40
Mountains, wilderness and recreation, above 6000 ft.	15	Desert	20
	100		100

The Nevada area has very little timber, confined mainly to mountain Juniper and subalpines. The remainder of the Nevada sector, including much of the National Forest area and all of the surrounding plateau area, is of the semi-desert, sagebrush grazing type. The northern half, outside national forests, is in a Taylor grazing district.

California's forest area of approximately 20 million acres supports a timber stand estimated to total about 363 billion feet. Present national forests are mostly in the mountains, all in the pine region, none as yet in the redwoods. Millions of acres of land, running through every topographic class, are used for the grazing of cattle and sheep, which forms a major industry of the State. Relatively little of California's land area is in crop agriculture. Of the total arable area of 20 million acres, only 12 million are irrigable, 8 million now under irrigation (canals or wells), and 6 million agriculturally cropped. Two-thirds of the arable area and over one-half of the 7-million State population are in the

southern half of the State, which has only one-third of the total rainfall. Absence of rain in the summer, six months over most of the State, makes irrigation imperative for intensive agriculture. Water is thus the absolutely limiting factor of both agricultural and urban development in California. Ninety percent of the water comes from National Forest land. With irrigated agricultural land values commonly $500 to $1000, and in citrus orchard land running to $5000 per acre, there is no other area in the United States where such large and such concentrated human values are so completely dependent for their existence upon the wise management of their contributory mountain and foothill lands. In 1936 over 23 million persons traversed the national forests of California of whom some 7¼ millions, or the equivalent of more than the total population of the State, made recreational use of them. Recreation thus raises major national forest problems, both of administration and of land use.

The California Station interprets its obligation to be that of contributing, for its total area, not only to the knowledge required for better management and utilization of forest land and its resource crops, but toward the integration of that knowledge in better land use policies and practice, both in national forest lands and all others in the areas of national forest influence, coordinating the land and resource uses of all toward sustained land productivity designed for optimum stabilized human prosperity in those areas.

The Station was established July 1, 1926, with a staff of 4 technical men and 2 clerks. In 1936, there were 32 permanent technical staff members and 12 clerks, 58 technicians appointed and 42 unappointed, besides a force of relief workers which at its peak has reached nearly 1,000. At the establishment of the Station, its activities were only Forest Management (Pine Region) and Forest Survey (Type Map). It now has divisions of Forest Management (Pine), Forest Management (Redwood), Range Research, Fire Research, Forest Influences, Forest Survey, Forest Products and Forest Economics, besides the Institute of Forest Genetics which was acquired by the government in 1935.

Experimental Forests

The Station now has 10 experimental forests or ranges as follows:

For Forest Management

Feather River (Approved). Plumas N. F. 3,970 acres. West-side mixed conifer, sites II and III. Branch Station established, also plot studies on previously established withdrawal of 353 acres surrounding headquarters. Utilization road system completed on Experimental Forest.

Swain Mountain (Approved). Lassen N. F. 6,080 a. West-side W.Fir-R.Fir, site III. Not developed.

Stanislaus. Stanislaus N.F. Ponderosa pine-sugar pine, sites I and II. Branch Station and small 30-acre experimental area established. An adequate tributary experimental forest is pending but unfortunately delayed in getting through to approval.

For Forest Management and Range Research

Black's Mountain (Approved). Lassen N.F. 10,252 a. East-side P.P.-J.P., sites III and IV. Branch Station established, and timber inventory, establishment of management compartments, and utilization roads completed.

For Range Research

Burgess Springs (Approved). Lassen N.F., tributary to Black's Mt. Branch Station which is its headquarters. 1,148 a. P.P.-J.P. east-side cut-over forest range devoted to cattle grazing problems. 537 a. fenced and improved.

San Joaquin (Purchased). Near Sierra N.F., 4,200 a. Sierra foothill oak-grass type, representative of 20 million acres of California foothill land. Branch Station established. Devoted to cattle range problems in valley and foothills.

Forest Genetics

Institute of Forest Genetics (Donated). Adjacent to Eldorado N.F., in Sierra Nevada foothills P.P. second-growth zone. Approximately 85 a. with 25 a. additional in process of purchase.

For Fire Research

Mt. Shasta (Approved). Branch Station established. Shasta N.F. designated by Region as an experimental fire forest, having the most serious and concentrated fire problem in this Region. An area of several thousand acres of dense chaparral tributary to Pilgrim Creek center has been set aside for experimental fire work in brushland; representative of over a million acres of high quality timber land captured by brush as a result of fire or logging followed by fire.

For Forest Influences

San Dimas (Approved). Angeles N.F. 17,000 a. Chaparral type with scattered timber at high elevations. Branch Station and extensive installations established. Administrative Headquarters at Glendora.

Kings River (Approved). Sierra N.F. Two units established: (1) Big Creek Unit, 300 a., woodland-grass type, elevation 500 to 3500 ft. Installation completed. Branch Station established; (2) Teakettle Creek unit, 2,000 a. White fir-red fir type, alt. 6500-9000 ft. Installation and headquarters

under construction. Two other units, in pine-fir type, elevation 3500-6500 ft., and in subalpine type, elevation over 9000 ft., respectively, are in process of selection. Administrative headquarters at Fresno.

In addition to the above there are the following:

Research Withdrawals (no Experimental Forest status)

Devil Canyon. A watershed study unit. San Bernardino N.F. Chaparral slopes with mesophytic stream-bottom vegetation. Branch Station established, with an erosion-control-plant nursery, and two small tributary watersheds where special intensive studies are in progress.

Butterfly Valley. Plumas N.F. A management research unit. 400 a. mixed conifer, site II. Fenced and accessible, awaiting contract cutting.

Badger Wells. Modoc N.F. A management research unit. 1500 a. Virgin east-side ponderosa pine type, site IV. Research value severely damaged by recent Dendroctonus epidemics.

Additional needs. The Station urgently needs, besides the above, four additional experimental forests and an experimental range, as follows:

For Management Research

One in the Sierra Nevada foothills second-growth pine forest. More than a quarter million acres of this second growth, succeeding the cutting of the mining days, are just reaching or approaching merchantable size, and destructive exploitation by migratory small mills has already begun and is progressing at accelerating speed.

Two in the Redwood Region, if possible in connection with the acquisition of national forests, to meet the urgent problems of older redwood forests of Humboldt County and the younger ones of Mendocino, respectively.

For Range Research

An experimental sheep range, preferably in the foothills tributary to the Sacramento Valley, for which the sheep men are already making urgent demand, to give to that industry help such as is now being given to the cattle industry through the San Joaquin Range.

For Watershed Research

In the not too distant future, a northern experimental watershed forest. This should be in one of the watersheds tributary to the Sacramento Valley, where many conditions such as the soil and its erosibility, and cover and rainfall, are significantly different from those found in the southern part of the State

FOREST MANAGEMENT - PINE

The California pine region covers a gross area of 15 million acres, of which about 9-3/4 million acres bear virgin timber. Of a gross total stand estimated at 263 billion feet, 195 billion is available virgin timber. About 8-1/2 million acres, bearing 100 billion feet, are in federal ownership, practically all being in national forests (National Park timber is classed as "unavailable"). The balance is practically all privately owned, state ownership being negligible. The commercial timber species are the pines (ponderosa, Jeffrey and sugar) and Douglas fir, white fir, and incense cedar.

The present timber cut is only about two-thirds of the average before the depression. With a normal annual lumber cut of about 2 billion feet b.m., the annual commodity drain is equivalent to somewhat over 4½ billion feet b.m. Insects, fire, and decay take at least 1¼ billion feet in addition. The total annual drain is, therefore, one of serious proportions.

Nearly 5 million acres are cut-over and in various degrees of restocking or deforestation. Over 2 million acres have been taken over by brush. On the large foothill area cut-over in the early mining days, 300,000 acres have escaped subsequent fire and other abuse sufficiently to have produced a second-growth stand now nearing merchantable size and amounting to 4 or 5 billion feet. Privately owned, destructive exploitation is already beginning to make alarming inroads upon it.

Forest management research has been in progress in this Region ever since the establishment of the Forest Service. Its results now show that even the best forest management practice of the last thirty years leaves us far from achieving the regulated stands necessary for economic sustained yield. Neither regeneration nor growth rate has come up to expectations or requirements. Losses of mature timber are intolerably heavy. Our problems are now those of bringing back to resource productivity the large areas of once valuable timber land now devastated or unproductive as a result of destructive lumbering, fire or other abuses; in management policy of the increasing of forest growth, completion of stocking and balancing of stand structure, such that sustained yield may be supported by the optimum crop production which alone can justify it; and of helping to secure on private as well as public forest lands the application of the best forestry practice made possible by the knowledge attained.

On this basis the Division is carrying on the following studies:

Management

Past work has indicated many promising means toward the management objective, but these need testing and demonstration upon a large scale which has never before been available.

Sustained Yield, Black's Mountain. This project is the first such undertaking. Its aim is to develop the management and silvicultural practices necessary for sustained yield on the ponderosa pine of the poor sites of the northeastern part of the State. With the aid of a thoroughgoing compartment lay-out and transportation system, both of which are now completed, a logging operation will be carried on by the Station, which can be varied at will to meet varying silvicultural needs.

Surveys, inventories, and compartment lay-out are completed. Utilization roads and other physical facilities are near enough completion to begin logging this summer. Insect control investigations will be conducted by the cooperation of the Bureau of Entomology.

Prediction and Regulation of Growth in Selection Stands. Attack upon this problem is by the analysis of sample plots and cruise records widely distributed. The aim of the work is the establishment of an ideal or normal stand, with which comparison of actual stands will indicate necessary treatment. Reasonable success has been obtained in determining the contributions to growth by new trees reaching utilizable size and in allocating final volume to component species. The predicting mechanism for gross growth has been greatly strengthened by the application of curvilinear correlation analysis. Methods of correcting for mortality are still unsatisfactory. Adequate information for this management field will require more comprehensive research than it is now possible to provide.

Silviculture

The silvicultural studies of the station have given fairly distributed attention to the two fields of natural reproduction and forestation. The former will doubtless be the major means of forest regeneration in this Region where lands have not been subject to too much abuse through the harvesting of the virgin timber, or by fire, or both. With too great removal of seed trees and denudation by severe or repeated fires, however, the invasion of brush is a most serious menace to forest regrowth. Its density when established allows neither the light nor the soil moisture necessary for the growth of tree seedlings, in competition with it, and artificial forestation becomes at the same time necessary and abnormally difficult or costly. For the final attainment of the kind of a tree crop desired, silvicultural research must give large attention to cultural treatment of reproduction and second-growth stands. Only fragmentary work has thus far been possible here, in this direction. The matter is already becoming critical in the 300,000-acre block of more or less even-aged second growth, now about 70 years old, which has followed early day cutting for the mines in the Mother Lode region of the Sierra Nevada

foothills in northern California. This compact body of second growth is practically all below the national forest boundaries, and an adequate attack upon its problems is impossible without the acquirement of an experimental forest in this area.

Natural Reproduction

Studies in the field of natural reproduction now in progress include the following:

Seed production and incidence. Phenological studies are a fundamental necessity for sound silviculture. Among our studies are microscopic studies of the progress of fertilization and the effects upon flowers and cones of environmental factors such as freezing temperatures, etc. Seed production is studied by means of cone and seed counts, and seeding incidence by the use of seed traps.

The seed crop for 1936 was twice as heavy for ponderosa pine as the average of the preceding three years, over 8 times as heavy for sugar pines and only one-tenth as heavy for white fir and incense cedar. The trap catch per acre for this year was, in round numbers, P.P. 11,700; S.P. 25,800; W.F. 2,900; I.C. 7,850; total 147,300. Five hundred additional seed traps which are ready for 1937 use will be placed in accordance with statistical sampling requirements.

Seedling incidence and survival. These important phases of natural reproduction are attacked by means of charted quadrats. A dearth of seedlings during 17 years of subnormal precipitation was succeeded in 1935 by a crop averaging 16,000 per acre, but white fir and incense cedar comprised 99.5 percent of this crop. Bare soil is most favorable for germination with litter and trash somewhat less so, and the low bear clover cover very unfavorable. The seedling incidence quadrats, examined subsequently for the fate of the seedlings, show that mortality was heavy on all sites, only 19 percent of the seedlings surviving the first summer. Survival is best under the low cover of bear clover and poorest on trash-covered and bare soils. Frost, drouth, rodents and insects take the highest tolls. Rodent destruction is most severe in the valuable pines.

Logging damage and brush competition. Charts of 780 quadrats in the cut-over sugar pine-fir type at Stanislaus Branch show an increase of brush from 10 percent coverage of the surface after cutting in 1929 to 31 percent in 1934. Soil disturbance by logging favors high-brush invasion. There is a striking difference in the ability of different shrub species to spread on cut-over land. The most aggressive are Ceanothus parvifolius and C. integerrimus, with the snow brush (C. cordulatus) and the green-leaved manzanita (Arctostaphylos patula) at the tail of the list. Studies of logging damage have shown that tractor logging disturbs about the same relative area as intelligently regulated donkey logging. The major advantage of tractors in respect to damage is their possibilities for reduced destruction of advance growth and reserved trees.

Site Factors. These studies aim to determine the physical conditions which limit natural reproduction and which are subject to control by silvicultural treatment favoring the pines. Instrumented stations at the Stanislaus Branch are furnishing data which justify extension of observations over a much wider range of forest and conditions.

Seasonal Growth. Diameter and height growth are being measured for different species at different altitudes. Measurements are under way at Stanislaus and Feather River and are being started at Black's Mountain.

Forestation.

In the field of forestation, great advances are in the making in knowledge respecting the requirements for successful seeding and planting.

Direct Seeding is being extensively studied by seedpots. With unprotected seeding, rodent destruction of pine seed is so great as to make the work fruitless. Rodent screens result in establishment comparable to that from planted stock. Survival was better on burns than on other sites. Seeding on burns is more effective when done quickly after the fire than under any other conditions. Uncontrolled competition from herbaceous growth reduces height growth of seedlings as much as 50 percent below the growth with the herbs controlled by grazing.

Feather River Nursery. At this nursery 78,000 trees were produced in 1936. In the fall of 1937, 90,000 ponderosa and 50,000 Jeffrey pines will be ready for outplanting.

Planting. Research in this direction has revealed significant results in respect to the effect of frost on species; the effects of root pruning; soil moisture content under brush and other cover competition; the effect of rabbit damage, which is severe. Planting survival, like that from direct seeding, is best on burns. Frost which killed 75% of ponderosa pine planted stock killed only half as much of Jeffrey pine. Root pruning to 8-inch length decreased survival significantly below that of stock pruned to 12-inch root length. A spray intended to protect seedlings against rabbit damage had little effect on that score but increased strikingly the survival of the stock against other hazards. Further experiments will be carried on.

Summary.

To the problem of restoring to forest production the vast areas of more or less seriously devasted cut-over lands which are rapidly accumulating in private ownership, the silvicultural studies above indicated apply in considerable measure, but the problem of what we are going to do with these areas is of such urgency that much more intensive study of its specific factors is needed than present resources make possible. For the management studies, also, additional projects like the Black's Mountain one are urgently needed in forests of better sites than at Black's Mountain. Experimental forest establishment is now such

as to make possible at least three such projects if funds were available. Work in the cultural treatment of second-growth in the pine region finds its most urgent need to be an experimental forest in the Sierra Nevada foothill second-growth area.

FOREST MANAGEMENT - REDWOOD

Of a total area for the redwood region of approximately 2.4 million acres of land bearing commercial timber or capable of growing it, the redwood type occupies a little over 1.4 million acres, of which 1 million acres bear virgin redwood timber totalling nearly 70 billion feet, b.m. Ninety-nine percent of this virgin redwood is in private ownership. The region contains no national forests. The remainder of the region's gross timber area and of the 81-3/4 billion feet of total timber stand is in a Douglas fir belt which, in the main, lies between the redwood type and the pine-bearing coast range mountains. 440,000 acres of the redwood type is cut-over land, of which 11 percent bears merchantable second-growth, 15 percent is deforested, and the remainder is in various degrees of restocking. The majority of the latter is poor.

Redwood logging has been exceedingly wasteful and destructive. The annual commodity drain is now the equivalent of about one-half billion feet b.m., of which 70 percent is lumber. This total is only about 60 percent of the corresponding drain before the depression. Non-commodity drain is very much lighter in the redwood than in the pine and adds only the equivalent of about 60 million feet b.m. The total drain, therefore, would be within 900 million ft. b.m. equivalent, on the pre-depression rate of cutting, to which it will doubtless return.

The redwood research program, begun in 1931, in the absence of a government controlled work center has been confined to an attack upon a few of the more pressing immediate obstacles to sustained forest management. This has necessarily resulted in delay in the initiation of many fundamental studies which require long-time continuance, either in instrumental installations or in periods of continuous observation.

Concentrating limited resources upon a few of the most urgent problems, however, has resulted in immediate dividends. Major attention has been devoted to studies of logging and of natural reproduction. Other studies have been of planting, different phases of mensuration, and slash disposal.

In redwood logging the use of large steam and electric donkeys, and particularly of slack-line yarders, is undoubtedly one of the most serious obstacles to better woods practice. Results of planting and reproduction studies in the redwoods confirm the conclusion from management studies in other similar all-aged types, that sustained productivity, at least during the period of transition from virgin to managed stands, is practicable only with selective logging. This is with full recognition that selective logging in itself is no guarantee of the accomplishment of

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silvicultural ends; but it is a necessary prerequisite to their accomplishment in the redwoods. Selective logging is impossible with slack-line yarding, and difficult and costly with heavy, high lead equipment. Tractor logging, on the other hand, is ideally adapted to tree and log selection in any degree. It was for this reason that a study of logging, and particularly of yarding methods, was undertaken.

Preliminary results of these studies have shown very definite advantages in the use of lighter, more flexible equipment, particularly tractors, both in saving reserved trees and reproduction and in the cost of the logging. Due mainly to the latter result, a remarkable improvement has already taken place in redwood logging. During 1936 probably one-half of the total yarding was done with tractors, while only three years before, they were considered of little value except for small areas where light timber stands or inaccessible location made steam logging impracticable.

The Henry Creek selective logging and milling study, in which this Division cooperated with that of Products, is of particular interest to the redwood industry because it was designed to determine the conversion value of redwood trees and logs by diameter and grade. When completed it will show the comparison between costs by size and grade from the standing tree to the green chain, with the lumber values realized from the same sizes and grades.

Slash disposal. This subject involves several of the most important problems in redwood management. One of these is the mechanics of slash removal for hazard reduction, where the volume of debris is as great as it is in the redwood region. Of even more interest from a research standpoint are the effects of slash and slash fires upon the establishment and growth of reproduction and the growth of residual trees. On tractor-logged areas slash disposal fires have been much more destructive during the last few years than the yarding. Our studies have already resulted in recommendations which if followed would largely eliminate crown damage without much additional cost. The problem, however, is so fundamental and far reaching that the Station is not willing to commit itself to anything less than an equally comprehensive attack, and prefers to wait until commensurate resources and cooperation are assured.

Natural reproduction. The first study in this field included an extensive sampling of the major cut-over areas, designed primarily to give a broad picture of current conditions which could be used as the background for more intensive research later. It included a determination of the stocking density on representative areas, particularly those logged since 1920, and the probable influence upon reproduction of such factors as methods of cutting, slash disposal, seed supply, elapsed time since cutting, type and density of vegetation, amount of slash and litter, grazing, and exposure and gradient. A large amount of data from the Henry Creek study has supplied the basis for a supplementary determination of the natural reproduction which may be expected on such selectively-cut areas. 328 permanent quadrats have been established on three sample areas within this area, which will be examined annually for five years and thereafter at 5-year intervals.

These studies have refuted the traditional idea that natural seeding cannot produce new forests in the redwoods, and have demonstrated the impossibility of obtaining adequate forests from redwood sprouts alone.

Planting. The study of planting was the first project undertaken in the redwood management program. The immediate objective was the determination of the results of the commercial planting done by redwood lumbermen from 1921 to 1931 when it was discontinued. The study has demonstrated the fundamental unsoundness of that planting, particularly in planting pure redwood, and the necessity for much more knowledge to make any redwood planting program sound. A manuscript on "Commercial Planting on Redwood Cut-over Lands" is in course of publication.

Mensuration. Enough work has been done on the study of site classification to check the earlier work of Bruce and Schumacher. It has shown that in general it is safe to use the tables which Bruce published in 1923. Further extension of them is needed and should be undertaken as rapidly as possible.

There are still no satisfactory volume tables for redwood, in spite of the obvious need for them in cruising and in logging and management studies in general. A start was made on the collection of the necessary material in the field season of 1935. Such measurements are very time-consuming. Data from only 170 trees were obtained at that time and present resources will permit only slow progress on this necessary project.

Summary. Further selective cutting studies such as the Henry Creek are needed. Additional woods and mill studies in cooperation with Products are urgent beyond present possibilities, for the completion of knowledge of yield and returns from redwood land of different stand composition and site qualities, and with better methods of harvesting. The natural reproduction and planting studies have so spectacularly shifted the emphasis of the redwood region regeneration problem from total clear-cutting and planting back to natural reproduction, except for specific cases, that these studies must be extended and completed. Adequate study of the slash problem, which fundamentally conditions management progress in this region of exceptional productive capacity, stands still until more comprehensive attack is possible. The necessary long-time and fundamental studies in the main await the securing of national and experimental forests.

FOREST GENETICS

Forestry is still dependent upon the wild trees of the natural forest, notwithstanding that one of the most powerful factors in advancing agriculture from its primitive beginnings to its modern efficiency has been the development of new and improved crop plants, now increased enormously in its effectiveness by the advances in the relatively new science of genetics. One of the major reasons why forestry has so long been deterred from obtaining the benefit of this powerful aid is undoubtedly the long time required to grow a forest crop, from seedling to seed. That forest genetics and its application in growing better trees for man's needs will require a long time is all the more reason for beginning them at once.

The only institution in the world thus far devoted exclusively to this field is the Institute of Forest Genetics, at Placerville, California. It was established in 1925, under private endowment, acquired by the government in 1935 and assigned to this Station. It has already in its arboretum the most complete representation in existence of the pine species of the world, comprising over 100 species and varieties from 40 countries. It has already produced results of practical value, for example in identifying and locating parent trees whose seed has been demonstrated to produce trees of unusually rapid growth or of high quality in other desirable characteristics.

The Institute is one of applied science, investigating the underlying genetic factors and principles, but always with the aim of applying them to the production of better trees for the forest, and of improving silvicultural practice. The work of the Institute is being concentrated, for effectiveness, on the genus Pinus. The major lines of work thus far are: Species and Progeny Tests, and Breeding (hybridization by controlled pollination).

Species and progeny tests. These tests include the selection of trees of the best growth and development from many geographic and climatic areas, also planting their seed for detailed observation and comparison of their progenies. Thus it is possible to isolate forms whose excellence is genetical and hereditary out of those in which it is sporadic or environmental. Inherent growth vigor, and other qualities such as branching habit, are shown to be hereditary. The vigor of ponderosa pine in California is shown to vary inversely with the altitude. Replications of former progeny plantings, planned for safety of conclusions, have been made this year with the benefit of personal advice in respect to the scheme by Prof. R. A. Fisher of the University of London, which greatly increases their statistical validity.

Breeding. The Institute has given considerable attention to breeding by controlled pollination and this work will be extended. One example of its results is the crossing of Monterey pine, which is the fastest growing of our native species, with Coulter pine, which possesses frost hardiness which the Monterey lacks. Hybrids of this cross are over 20 feet high at 8 years of age and withstood well the extreme winter of January, 1937 which killed nearly all of the straight Montereys in the Institute plantings.

Hybridization, without special supplementary techniques, yields forms that are notoriously unstable in reproduction by seed. Tetraploidy, or the doubling of the chromosome number of the cells, which can be accomplished by special treatments, is being used. This imparts the ability to breed true, along with high fertility. The time factor is greatly reduced, both in establishing stable forms by hybridization, and in progeny tests, by the unexpectedly early age at which flowering and seeding is being obtained in the Institute arboretum, where trees of many different species are now producing cones, some of them having begun at 3 years of age.

In all the lines of Institute work volumes of data have been accumulated, the thoroughgoing analysis and evaluation of which was made impossible by the trying conditions of private financing under the depression. This analysis is being given first priority under Station control, because of its significance in respect to guidance of future work not less than its intrinsic values.

Rate of growth has thus far had emphasis because of its ease of study for the initial breaking into a new field, rather than because it was supposed to be the most important quality for the forester. As resources permit, however, the genetic aspects of other tree qualities will be investigated. Such additional characters are, for example, tree form, branching habit, and quality of the wood.

Looking toward useful expansion of scope, two new special fields have recently been manned.

Plant Physiology and biochemistry. The applications of such work to genetics are manifold. Exploration will be undertaken of the possibilities of speeding up vegetative propagation of conifers by the use of hormones. Photoperiodic treatments also offer considerable promise of affecting importantly such qualities as frost resistance and other tree characters.

Cytology and taxonomy. The field of genetics is filled with cytological problems, for example in the matter of doubling the chromosomes which has been referred to. Taxonomic work is urgently needed in order to check the identity of forms which have been introduced at the Institute and to work up accumulated data on the identification of the juvenile forms of the many pines in the Institute's plantations, since most taxonomic work in the past has dealt only with the mature characters.

FIRE RESEARCH

In spite of nearly 25 years of constant attempt to better fire protection performance, since DuBois in California made the first thoroughgoing analysis of the problem in his "Systematic Fire Protection in the California Forests," in 1914, the fire risk incident to increasing automobile travel to the forest has so nearly kept pace with increasing protection efficiency that fire is still the major burden of every forest administrator. There are still an average of over 2000 fires per year in California, burning over more than 500,000 acres and causing damage of more than $1,000,000; and of these fires, nearly 75 percent are man-caused. This gives a "fire rotation" so short as largely to nullify the possibility of consistent forest regulation and profitable sustained management.

After DuBois, the next fire research highlight was the analysis of fire detection, get-away and attack times, by Show and Kotok in 1919. Results of those analytical studies continued to appear from time to time. The administrative fire organization also gave intensive study to fire problems, chiefly those of fire suppression organization. Everybody desired more fire research, but it was another full decade before specific appropriations were forthcoming.

Fire research with a formal section organization at this Station began in 1930 and the Region cooperated by designating as an experimental fire forest the Shasta National Forest, where the most acute fire problem of the California Region was combined with the most intensive fire organization of the Region to afford excellent advantages for fire research.

Detection

First attention was given to the problems of detection, including the development of special techniques for visibility mapping and the selection of lookout points, with specialized studies of radius of vision under varying positions of the sun, haze and smoke conditions, and seasons of the year. These studies were completed just in time to permit in 1933 the use by the Region, under Station direction, of the new CCC personnel in a complete revision of the lookout system of the Region; organically tied in with similar revamping of the lookouts of the National Parks and the State Division of Forestry.

Organization Planning

Revision of the lookout systems brought immediate necessity for revision of the communication and road transportation systems of the national forests, for which the Station developed technique and gave technical guidance to the Region. These various improvements of the physical basis for fire control were finished in 1936, giving the Region a foundation never before available for fire performance efficiency.

Fire Behavior

This problem now occupies the main activity of Station fire research. Significant further advances in fire suppression efficiency must have a foundation of greatly increased knowledge of how fire behaves and the factors which affect its behavior. Station study of this problem has been through the observation of approximately 300 test fires. Among the factors affecting spread, those studied have been wind, slope, moisture content, size and arrangement of fuels, and degree of compaction. This work is still in process.

In respect to wind, a significant improvement has been developed in the hot-wire anemometer. By anemometer readings spaced from near ground level to the tops of the trees in a heavy, even-aged timber stand, as well as in an adjacent open area, reliable information never before available is being obtained in respect to the velocity and behavior of wind near the forest floor as compared to that in the treetops and in the open.

In respect to fuel moisture content, drying oven determination was found to be too inaccurate for this purpose and a much more accurate method has been worked out by the use of special solvents in a reflex column. The ignition and rate of spread as affected by size and arrangement of fuels has been worked out for one specific fuel, ponderosa pine needles, to the point of expression in a ratio V/S between the volume of voids and the surface area of the fuel, per unit volume. This work will be continued with other types of fuels.

Eradication of Firebreak Vegetation

The feasibility of extensive use of firebreaks is dependent upon the possibility of maintenance. The completion by the Region of the 600-mile Ponderosa Way along the Sierra Nevada front, by CCC labor, raised critical need for solution of the maintenance problem of eradication of firebreak vegetation. The killing of trees has been solved by the Station, without the poison hazard of arsenicals, by the use of Diesel oil. For soil sterilization against the growth of annuals, nothing yet takes the place of arsenicals. Study of this problem is being continued, together with the problem of erosion raised by the sought-for elimination of firebreak vegetation.

Southern California Studies

For next year, besides the continuance of behavior studies and the analysis of their results, together with the development of a field laboratory for these studies, the largest new development will be a study of the acute fire problem of the chaparral territory of southern California. Here there is a complex of conditions which create a very distinct and difficult fire problem. The impenetrable and highly inflammable high-brush cover, the long dry period with a 12 months' fire season, and the prevalence of precipitous topography result in fires which always crown and are characterized by intense heat, excessive rapidity of spread and frequent spotting. Slow and difficult access by foot, with scarcity of water, make fires extremely dangerous to handle. Here, by the construction of concreted collection reservoirs, is being attempted, the solution of the problem of providing an especially dry country with strategically distributed water supplies for modern tank truck fire attack.

RANGE RESEARCH

Livestock grazing is a major industry in California. The number of cattle and sheep in the State fluctuates considerably but averages about 2,000,000 cattle and 3,000,000 sheep. The cattle and sheep industry of California, as of most of the rest of the western range country, present the spectacle of an industry locally eating itself up through intesive and continued overgrazing. The carrying capacity of many range lands of the State has been reduced by one-third to two-thirds since American occupation. A second result has been the displacement of native plants by invading European immigrants. Most of these have been annuals. Some of them, such as bur-clover and alfileria, are of high forage value, but many of them are of low value. The displaced native vegetation has been largely perennials, such as the bunch grasses, of high forage value. Many of the Station quadrats established over the San Joaquin Valley and foothills show as high as 97 percent of the present forage to be annual plants. Annuals dry out early in our long rainless season and, instead of curing, lose heavily in their nutritive values. The diminishing fortunes of the industry, intensified by a long period of drouth, make it impossible for the operators to sacrifice present income to long-time good, or to make the investment in water and other developments which would be necessary to restore the range. In general, the stockmen are looking for salvation to the miracle of finding some foreign plant which will thrive under every abuse, instead of accepting their own responsibility for restoration of the range by conservative grazing practice.

Winter range is in the valleys and lower foothills. The traditional practice has been to drive flocks and herds to the mountains for summer range. The increasing closing of the spring-fall range zone in the intermediate foothills by settlement has brought about a tendency toward smaller use of summer range, through the feeding of supplements, the use of irrigated summer pasture, etc. The national forests graze only about 7 percent of the State's cattle and 10 percent of the sheep. In contrast to the private and open public range, however, Forest Service range management has resulted in considerable restoration of national forest ranges, in spite of heavy pressure for taking on extra stock during the War time and the period of subnormal rainfall which continued from then until 1935.

Range research was established at the Station in 1931. A year was given to surveys and orientation work and the development of improved yardsticks for the measurement of range conditions. A reconnaissance range and erosion survey was made of some 9 million acres of San Joaquin valley grazing land during this period. This work resulted in the selection for project attack of two major areas, the San Joaquin Valley and foothills, and the Eastside cut-over pine ranges.

San Joaquin Experimental Range

In 1934, after long search for the best location, the site of this experimental range was purchased and its housing, equipment and implementation were begun. The area is representative of the oak-grass foothills which surround the great valley, with an area of nearly 10 million acres. Its main objective is to determine the methods of livestock and range management necessary in this foothill type, to combine the greatest mutually consistent measure of animal production and value and of sustained forage productivity and nutritive value on the range.

Controlled Grazing. A careful inventory was first made of the forage resources and existing condition of the Range. 1936 was the first season of controlled grazing, in cooperation with the University of California. The latter owns the cattle herd and its Animal Husbandry staff directs that phase of the studies. Identical numbers of animals are grazed in duplicate pastures of three different sizes for determination of carrying capacity. The density of forage growth in a good year may be judged by a count of 37,300 plants of 8 species on a square-meter quadrat. Remaining ungrazed forage at the end of the season was also recorded. Beginning July 1, when the annual grasses dried up, one-half of each lot of animals was given supplementary feed of cottonseed cake. The result was a final weight difference averaging 90 pounds in favor of the supplemented animals. This added poundage was worth about $10 per animal at current prices (the supplemented animals being worth 50 cents more per hundredweight than the unsupplemented ones), while the supplemental feed which produced it involved a total cost of a little over $4 per animal.

Chemical analyses correlated with stages of plant development. Professor Sampson of the University Division of Forestry has cooperated by conducting a detailed chemical analysis of individual forage plants taken from this range in a number of different growth stages from germination to maturity. Results of several thousand analyses demonstrate changes in the chemical composition of individual species in different growth stages which are greater than the differences between many species at any given time. This work is of fundamental significance and throws into the discard most of the isolated plant analyses of past years. An example from many interesting results is the consistent differences between herbs, forbs and shrubs. Ash content is lowest in shrubs on the average, next in grasses and highest in forbs. The calcium/phosphorus ratio starts out in grasses and shrubs at approximately unity while in the forbs it is about 2/1. In the grasses the ratio remains practically constant throughout the life cycle. In both the others, however, it rises with vegetation growth, until by the end of the life cycle the ratio reaches, for the shrubs around 15/1, and for the forbs 20/1.

Artificial revegetation. Approximately 100 species of forage plants from other regions or countries are being grown and tested in a forage plant nursery. Those which prove able to stand the long, hot, rainless summers of this region are being tested on the open range, in competition with the existing plant cover.

Rodents. The Biological Survey has cooperated by making studies of forage consumption by rodents in different enclosures, each having a known population of a single kind of rodent. One of the outstanding progress results is that a half dozen ground squirrels per acre are found capable of consuming nearly half of the total forage production in that type.

Wildlife - Quail. The San Joaquin Range is the stage for a 4-agency study of factors influencing the population and management of the California Valley quail on the Range area, which is a typical habitat of this species. The University of California Division of Zoology, the Biological Survey, and both Administration and Research of the Forest Service are cooperating in this game management study, which is one of great local interest. Initial results of great interest are coming out of it and should be released within a few months.

Influences. A 9-plot erosion-streamflow installation at the Range is designed to throw light on the role of the foothill woodland-grass type cover in the regulation of run-off and erosion. It is still in the calibration period. It has shown the surprising result of practically no run-off or erosion, even under heavy precipitation. When the protective herbaceous cover is adequately maintained, this decomposed granite soil seems to absorb all the rainfall, even though the annuals composing this herbaceous cover form no semblance of a sod. But the water appeared again in the drainage channel 50 feet farther down the gentle slope, flowing down an underlying impervious stratum.

Burgess Springs Experimental Range

This Range, tributary to the Black's Mountain Branch, which forms its headquarters, was selected as typical of the cut-over pine ranges of the northeastern plateau. Its major problem is the determination of the role which livestock plays in the proper management of Eastside pine lands - what is the value of the range, what the effect of grazing upon pine regeneration, and what the whole relation of grazing to the other major land uses. Initial effort is concentrated upon the first two named.

Value of cut-over range. Forage yield was sought by determining the clipped dry weight produced on 835 quadrats gridironed over the area. Species composition of the forage and frequency of occurrence of species were likewise determined. Eighty percent of the forage was composed of 16 percent of the 114 species recognized. Cattle diet preferences were studied by continuous daily observation of the grazing animals for three days before each weighing. Preferences in species taken were found to change abruptly from week to week, without compulsion due to lack of any species. A few species, however, represented the bulk of the animals' choices, six species comprising 75 percent of them during the earlier part of the season, and 90 percent in the later part. Their preferences, thus written by the cattle themselves, disagree sharply with some long accepted Forest Service range plant palatability criteria, as discussed in the Station annual report. One of the most significant results of this

year's study was that this first-year cut-over pine range was found to have surprisingly high value, as judged by the gains made and the excellent condition in which the cattle were maintained. There remain to be evaluated the ecological changes involved in the gradual reversion of the area to pine forest.

Cattle grazing vs. pine seedlings. Of 5627 seedlings germinating on 834 seedspots planted the preceding fall, only 436 were alive in the following November. Of the 5191 that died, most were killed by drought, insects or frost. Only 1.06 percent were killed by cattle, and only 0.23 percent by actual grazing. It seems clear that cattle are not a serious menace to pine reproduction in the northeastern California region, at least under the conditions of 1936.

Salt consumption and water consumption on the range had need to be studied. Crude automatic electrical recording instruments were devised for both and are being perfected as opportunity offers. Very interesting data were obtained, the full interpretation of which is not yet completed.

Wild life - Forage preferences of deer. Careful observations were made of the forage preferences of the native mule deer three times during the month from middle May to middle June, before the cattle went onto the range. This was with a view to obtaining a measure of forage competition between deer and cattle. The two herbs Crepis sp. and Leptotaenia dissecta constituted together 60 percent of the total in May and 51 percent in mid-June, with no other species constituting as much as 10 percent. In only one case was there any evidence of the taking of grass. This seems to indicate that the early-season preference of deer is predominantly for herbs, with a small amount of browse but little or no grass, and that there is little competition between deer and cattle at that season. The above does not, however, tell anything about the later part of the season.

Western Range Survey

This survey of forage resources and condition which is being conducted throughout the West has been especially heavy in its time demands at this Station because of a complete detail survey of San Benito County which the Station has made because of the strategic position of that county in respect to the interlocking programs of several cooperating federal agencies.

FOREST INFLUENCES

In California the problems of water supply, flood and erosion are intensified by the rainless summers and the concentration of the annual precipitation in the winter months. For most of the region agriculture is dependent upon irrigation. Depletion of vegetative cover by widespread overgrazing in the foothills and mountains, and by fire, believed by large sections of the population to be beneficial and almost everywhere treated with carelessness, needlessly expose the soil. Agricultural malpractice on slope lands and crop use of slopes too steep for tillage add a quota by no means negligible, to the advancing destruction. In addition to the usual consequences of flood and erosion, a phase peculiar to California is that muddied flood waters seal up the water-spreading grounds which are the channels to vast valley underground reservoirs constituting the only water source for some two million acres of agriculture dependent upon pump irrigation. In this area for many years past the water level has been lowering due to use overdraft. Erosible soils, precipitous mountain slopes and rainfall often occurring in the sudden violence characteristic of arid regions combine to make erosion more prevalent and severe in the southern half of the State.

Forest Influences constituted the first new project undertaken by the Station after its establishment, having been approved in 1926. Prior to that time pioneer work upon it in California had been done by E. N. Munns, culminating in his report, "Erosion and flood problems in California", of 1923 to the State Board of Forestry.

The objective of Station work in Forest Influences is to develop principles of watershed management which shall insure the maximum yield of usable water compatible with adequate control of floods and erosion and with other constructive land uses. To this end two broad lines of study are being followed: (1) Fundamental studies of the nature and interrelations of the causative or conditioning factors of streamflow and erosion, including climate, soil, physiography and geology, and their expression in vegetation, together with the effect of various manipulations of the land and cover, as by grazing, fire, cutting and planting; (2) experimentation in methods of erosion control, especially with respect to situations critical for national forest administration, such as road cuts and fills, overgrazed mountain meadows, and areas denuded by fire. The fundamental studies divide roughly into watercycle studies, watershed studies, and supplemental studies.

Station Influences research is distributed geographically as follows:

Southern California

San Dimas Experimental Forest: Major center, complete watershed influences installations and studies

Devil Canyon Branch: Nursery and limited watershed studies

Section-wide studies: Floods, erosion, and their control

San Joaquin Valley

Kings River Branch:

Big Creek Unit: Foothills woodland-grass type

Teakettle Creek Unit: Pine-fir type, 7000 ft.

Northfork watercycle installation: Woodland and pine types

Sacramento Valley

Kennett: Erosion control and reforestation of smelter-fume denuded area, oak-pine type

Redding Erosion Plots: Foothill brush type

Berkeley

Plots and lysimeters, foothill brush type

Tank installation, University Oxford Street tract

State-wide Studies

Flood survey and control; erosion survey and control climatology

The basic studies are carried on by means of the following methods:

Water Cycle Studies

Run-off and erosion plots. These are oblong, 1/40 acre in size, surrounded by board borders to keep the plot isolated from outside rainfall run-off, and supplied with silt traps, run-off measuring cans, electrically operated devices for recording run-off rate, and meteorological equipment. They are usually set up in adjacent triple pairs, one pair being burned off yearly, one pair burned off and left to recover, and one pair kept intact. Some results in southern California are: Run-off from denuded plots 5 to 50 times as great as from vegetated ones; eroded material carried, 50 to 500 or more times as great; plots once denuded regain most of their regulatory capacity in four or five years. On the Northfork plots, in granite soil and brush cover, was shown the important effect of rainfall intensity, light rainfall producing practically no erosion even from denuded plots, while heavy intensity produced even greater differences than in southern California. The Berkeley plots, on heavier, less erosible soil, showed smaller differences than those in lighter soils.

Tanks. Plots show the run-off from given rainfall, but do not show the soil percolation or seepage relation. To determine this, a battery of tanks was set up at Berkeley, averaging about $2\frac{1}{2}$ x 6 feet surface dimensions and 30 to 36 inches deep, set up on a slope and implemented like the plots,

except for bottom drainage take-off, leading to separate measuring tanks for seepage water. Filled, by series, with different soils having the horizons in the same order as in nature, they were covered with forest litter, then treated in a manner similar to the plots. They showed that the percolation varied inversely with the run-off, but leaving between their sum and the received rainfall a difference which was apparently to be accounted for by transpiration or evaporation, or both.

Laboratory tests. The results of the plot and tank experiments suggested an hypothesis of the mechanism of the effect of litter upon the water cycle, to replace the traditional one of sponge absorption which had been considerably damaged by the attacks of the engineers. Taking the problem to the laboratory, clear water, percolated through a battery of glass cylinders filled with soil, produced a curve of percolation rate which remained a wavy level line for two weeks. Switching then to muddy water the percolation curve dropped to nearly zero within a very few hours. This confirmed the hypothesis that the primary factor in run-off and erosion protection by a forest litter is the maintenance of the percolation permeability of the soil, which is destroyed by muddy water through the sealing of the channels by the suspended colloidal particles. This litter action in maintaining percolation is permanent, as the percolation tank experimentation showed it to be, instead of vanishing in a short time as would the sponge absorption as soon as the litter reached saturation.

Watershed Studies

The main difference between our present Influences experimentation and that of the past is in the fact that we have carried out semi-laboratory research such as the above, to isolate the effects of individual factors, before attempting whole watersheds in which so many factors are inextricably woven as to make their segregation impossible. After the plot and tank experimentation, the next step is to carry the experimentation to watersheds. This is now being done on the experimental watershed forests and other watershed experimentation areas, such as San Dimas, King's River, etc. These watershed installations must, however, go through a calibration period of some five years before subjecting them to denudation treatment by small sub-watershed units, similar to the treatment of the plots.

San Dimas Experimental Forest

This forest, as has been stated, is our largest and master installation, which includes extensive concrete dams, wiers, flumes, etc., as well as buildings, roads and trails and equipment. Manipulation of its chaparral cover will be aimed at the factor of fire. In spite of the heavy burden of construction, the research observation and record have been commenced as fast as installations of various kinds were completed. Two years' streamflow record for ten large watersheds and six small ones indicate run-off coefficients from well vegetated watersheds, ranging from 1.3 percent to 7.8 percent of total rainfall. Reservoir deposition, in the case of one watershed, was enormously increased by the erosion from a few hundred feet of county road which was put through one upper corner of the watershed just before our control became effective.

King's River Installation. This area with its several units will be devoted to the effects upon stream-flow and erosion, primarily of overgrazing and lumbering, fire being secondary.

Special Problems

Many of these are being attacked. One is the problem of transpiration use of water by plants, against the frequent argument that the chaparral should be burned off the mountainsides to save the water which it consumes. The Y-canyon experiment on transpiration by mesophytic riparian vegetation, at Devil Canyon Branch, and other special experiments are settling much of this controversy. Results from the batteries of lysimeters at San Dimas and Berkeley will make additional contributions to this phase.

An important special problem has been the design of a flume which will successfully carry and measure debris laden waters. The "San Dimas flume" is the result of cooperative development between the Station and the University of California Department of Hydraulic Engineering.

Other extensive special studies have been flood and erosion surveys and a survey and determination of the amount and rate of silting in existing major reservoirs.

Erosion Control

Examples of research in this field are the successful methods developed by the Station for the control of immediate erosion on burned areas by mustard planting; the contour-wattle method of vegetative erosion control on road cuts and fills; and erosion control on mountain meadows damaged by overgrazing, fire or adjacent lumbering. The Kennett project is a case of the repair of very severe erosion following complete denudation of some 75,000 acres of forest land by smelter fumes, and now seriously endangering a hundred-million-dollar reservoir project of the State water plan.

FOREST SURVEY

Vegetative Type Map

This project was one of the two major activities with which the Station started, on its establishment in 1926, and has been the main project under Forest Survey at this Station. The type map was then a relatively simple and rapid survey, of which the main object was to supply the need of national forests for cover type information as an aid to the planning of fire hazard reduction. Almost immediately, however, new uses for the data began to appear and most of them suggested desirable new extensions or refinements of the work which, for a few years, changed its standards rapidly. The usefulness of the type map material for all sorts of public and private purposes has been increasingly great. The present roster of users of type map material shows over 40 major projects of 9 federal and 4 state agencies, and a number of county agencies, besides colleges and other semi-public institutions, and individuals, some of the latter being in foreign countries.

Thus this project has grown from a modest beginning to one of the largest and most fruitful of the Station's lines of work. It contemplates the mapping of all of the state except the desert, cultivated agricultural lands and urban areas, amounting in the total to about 70,000,000 acres, and is now being extended to the adjacent portions of Nevada for the benefit of important cooperative projects in that region. Of this total, about 40,000,000 acres are already completed.

In the earlier part of the type map period the Station received little or no federal forest survey money and the major support of the project was derived from state and county cooperative contributions. These were forthcoming in considerable amounts because the maps were so useful that the cooperating agencies were willing to use their own money to speed up the work beyond the rate possible with official appropriations. During the depression the cooperative money all vanished and the survey is now dependent entirely upon federal funds.

On the inauguration of the nationwide Forest Survey, two years after the type map was begun at this Station, it seemed clear to the Station that in the absence of funds allocated to California for the Survey, our type map would have a value justifying its cost in the advance material which it would provide and which would greatly shorten and reduce the cost of the survey inventory when that should be undertaken here. Against much skepticism elsewhere in the Forest Service, this appraisal seems now to be sustained.

Publication of the maps is by color overlay on U.S.G.S. quadrangles. Of these the publication of 22 quadrangles has been practically finished to date. Ten are now off the press and 12 are in final stages of publication.

Collateral Values. Unexpected collateral usefulness has flowed from the type map. One item has been the determination through this map of the previous extent of forested lands, now deforested. This is possible by the relict trees or groups of trees which have escaped fire or the axe. It thus appears that pine forests formerly extended in the Sierra Nevada foothills down to 500 to 800 feet elevation but have now been pushed back for 10 to 30 miles to an average elevation of 3000 feet, which is approximately the upper climatic limit of agriculture.

The type map gridironing of the country has also resulted in the discovery of a number of new plant species and numerous extensions of the range of known species.

A major value of these maps in future years will be the present cross section which it will afford of the vegetation picture of the state which is continuously changing under the pressure of human forces.

Forest Resource Maps

These maps have arisen as an outgrowth of the Type Map in direct anticipation of approaching work on the Forest Survey inventory phase. They show the character and quality of all lands considered capable of growing commercial timber stands, as well as a broad and simplified classification of non-forest vegetation from the standpoint of land use. These maps are made available for immediate use by Forest Supervisors and others by means of inch-scale blue-line prints supplied with instructions for coloring by the user. Ultimately it is hoped that the timber volume inventory and descriptions of the various classifications may be incorporated and published in quadrangle units. There are contemplated 137 of such maps. Field work is completed on 20 and office work on about a dozen.

Timber Volume Inventory

The Station believes, for many reasons, that it is not desirable to undertake the regular inventory work of the Forest Survey until resources for that purpose are sufficient to prosecute it rapidly. In the meantime, the small funds and man-power which can be used for it are being devoted to a fundamental study of the methods which should be used to combine greatest accuracy and speed. To this end, an experimental inventory is being worked out on the Bidwell Bar quadrangle which covers about 468,000 acres of forest affording a typical cross-section of the major types and conditions found on the Sierra Nevada west slopes. The methods used in the Forest Survey in other regions will be applied to this area and analytically compared. The field work for application of the line-plot method was nearly completed in 1936. The Vegetative Type Map, as anticipated, is proving a great time-saving foundation for this work.

Land-Use Studies

The vegetation type maps have made a primary contribution to the land utilization studies in which the Station is engaged. These maps and data have also been made available to the Resettlement Administration for a study conducted by that agency in Santa Cruz County. For the Station Land-Use study, both type maps and forest resource maps have been used. Especially valuable has been the delineation thus afforded of the formerly timbered area, and the accompanying site-index classification of the timber-growing capacity of deforested as well as restocking land. For this land-use project, the Forest Survey Division has also contributed, by co-operating with the Station Division of Range Research in a correlation of vegetation types with livestock carrying capacity; and has collaborated with the Regional Division of Timber Management in the designation of timber working circles.

Collateral Research Activities

These include ecological studies, especially upon the soil indicator value of various tree and plant species; distribution maps for plant species; a vegetation-soil transect of the Santa Cruz Mountains; and a most valuable historical study of the Santa Cruz forest region, in which the lumbering history was reconstructed from more than 300 old sawmill sites which were definitely located and mapped with known dates of cutting and the areas cut.

Herbarium. The Type Map work since its beginning has systematically included the collection of plant specimens. This collection now totals 18,000. Duplicates are furnished to the University of California, which houses our collection and provides working space, in its herbarium.

FOREST ECONOMICS

Perhaps the earliest considerable piece of writing in the California Region having a major concern with economics was the study of "The Lumber Industry in California" by C. S. Smith, 1914, which was intended for official publication but was sidetracked by the Great War. Smith was Chief of the Office of Products of the then California District; and there, as well as later under the Station, Products has fallen heir to the bulk of economics work, in the absence of a formal economics organization. In the Station, the Forest Survey is separately organized; but the Wood Requirements phase of that Survey has been conducted by Products. It has carried, also, the immediate direction of the Station contributions to the major Service-wide economic deliverances of the current decade, including the revision of the Capper Report in 1931, the Copeland Report in 1933, and in 1934 the National Resources Board report on Land Use, in which the Forest Service was a major participant. Designation of Economics as a unit of the Station organization, staffed by a part of the slender Products personnel, dates only from 1936.

Since 1928, Station economics work here has been centered increasingly upon land-use studies.

Land Utilization

The primary aim of Station land-use studies is to serve national forest need, in the building up of land utilization principles and their application to forest and wild lands. The extraordinary diversity of the considerations, and the corresponding fields of knowledge, involved in sound land-use classification and planning makes its wise prosecution one demanding the cooperation of a wide range of specialists. Station work in this field has been carried on in cooperation, primarily with the land utilization staff of the Giannini Foundation at the University of California, but including University workers in soils, crops and many other lines, as well as the Regional organization of the Forest Service and other Divisions in the Station.

El Dorado County Study. For this first project undertaken, El Dorado County was selected as being representative of a considerable frontage of the Sierra Nevada mountains and foothills of the historic "Mother Lode" belt. These counties are now popularly known as the "cow counties", and are afflicted by numerous economic maladjustments which are apparently correlated with acute conflicts between major land uses. Since the days of '49, with its flare of mining, agriculture and timber cutting in the foothills, the history of this region has been one of destructive exploitation of natural resources, of which the ultimate end is resource exhaustion and economic and social bankruptcy. Here this consummation has been deferred and masked by the attack from time to time upon new resources.

The livestock industry, which succeeded the temporary crop agriculture for the mines, is dominant and doubtless permanent in the grassland lower foothills. Higher up, the timber cut in the mining days, in spite of continuing abuse has come back over some 300,000 acres to second growth now just nearing usable size and totalling over a billion feet b.m. The middle foothill zone, outside of its present development of specialized deciduous fruit agriculture in the scattered good soil pockets, is an area mainly of disastrous slashing and burning of timber second-growth of high potential value, to make low-value grazing. Much of the agriculture needs supplemental income, such as might be afforded by adjacent forest industries. Isolated settlement, especially toward the upper climatic limit of agriculture, increases unduly the costs of community services such as schools and roads; and an outdated organization of local government, with unskilled and haphazard administration, survives mainly by increasing state subventions. Meanwhile, recreation has grown to the proportions of a major industry, especially in the Lake Tahoe area, bidding fair to rival as an asset the mature timber, which now constitutes more than half the County's total taxable wealth.

The study was able to indicate a reorganization of land-use groupings, a constructive program of agricultural and industrial integration and of zoning combined with public acquisition of necessary forest-crop lands, which should permit execution of constructive land planning as a joint enterprise between the local units and the national forest, which occupies nearly one-half of the county. The results of the study are cooperatively published in California Agricultural Experiment Station Bulletin 572, "The Utilization of El Dorado County Land."

5-County Project. The El Dorado study was a pioneer undertaking, involving the breaking of new ground in both underlying philosophy and methodology, similar to that which was taking place throughout the Nation in this new line of research. On completion of the El Dorado study there was undertaken the extension of land-use research to the whole series of Mother Lode counties, running northward from El Dorado to the Feather River. This study is now in progress.

The general conditions of the El Dorado area continue throughout the belt, but localization of special agriculture, of industries, and of virgin timber bodies and second growth and the extent of their lumbering exploitation, make for a continually changing complex requiring specific analysis for each area. In this study, particular attention is being paid to phases which were missing from the El Dorado study or to which it was there impossible to give adequate development. Among these are the interdependence of valley livestock ranches and the progressive use of upper foothill and mountain grazing ranges; and the relation of the timber resources and of existing lumbering operations to the development of adequate timber working circles, combining both government and private timber wherever that is indicated, with a view to sustained maintenance of the resource. The latter phase is being worked out with the close cooperation of the

Regional Division of Timber Management. Through a member of the Taxation Inquiry, detailed to this Station, we have also been able to make a study, more thoroughgoing than would otherwise have been possible, of the taxation burden with special reference to timber, and of the functions and operation of local government in relation to the economic and social status of the area. These new or extended phases are being carried back to El Dorado County so as to complete the analysis for the 5-County series.

Much use has already been made of the Station's results in land utilization research by the Regional organization, which is urging their expansion and cooperating in their progress.

For attention upon the completion of the Five-Counties project, at least four areas cry for recognition, important to Regional activity in acquisition or management development. Attack must be restricted to one, with present resources, and the San Benito area has been selected.

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EXPERIMENT STATION

FOREST PRODUCTS

Forest Products research began in the California Region with the establishment of the Forest Service in 1905. It was transferred from the then District Office to the Experiment Station in December, 1927. Since that date most of the earlier Products activities, in subjects such as wood preservation, marine piling, and the air-seasoning of lumber, have gradually been closed out or transferred to the Forest Products Laboratory, and the Products work at the Station has been concentrated upon logging and sawmill studies. This shift has been in pursuance of the Director's policy that all lines of Station work should contribute directly to the major Station objective of advancing the better management of forest lands.

The object of the logging and sawmill studies is the determination of the costs of each conversion process, from the standing tree through to the sawmill shipping deck, for each log and tree, together with the exact amount and grades of lumber finally realized from them, so as to permit accurate individual log and tree valuation, by species, diameter and grade. Such data cannot be obtained from the lumberman, whose bookkeeping does not go beyond blanket costs per M, all species. The aim of the present studies is the determination of the relative economic desirability of different methods of lumbering, ultimately with reference to their adaptability to better silvicultural practice in the woods and the possibility of their integration with that practice toward regulated timber forests and profitable sustained yield management.

Thus far the studies have necessarily been confined to commercial logging or that practiced by lumbermen on Forest Service timber sales, the shortcomings of which have been pointed out in the Pine Management section of this report. The Station logging to be done on the Black's Mountain Experimental Forest will bring the opportunity for closer silvicultural tie, and that logging will be intensively studied from this economic point of view.

Since 1928 the Division of Products has conducted or participated in three logging studies, three major and four minor mill production studies, five major and two minor seasoning depreciation studies, one major and four minor surfacing depreciation studies. A few of these studies have been confined to white fir, which is the problem species of the pine region. The year 1936 was devoted largely to the analysis of 1935 studies, reanalysis of previous studies by improved methods, and a large amount of work in methodology for this rapidly developing technique.

One important result of these studies has been the demonstration to the lumber industry of the region that its cutting of trees below specified diameters (for high-site west side pine 22-24 inches), instead of helping to absorb the overhead costs of operation, has cost more in direct expenditures than the total returns from the lumber produced. At twelve inches stump diameter this loss may be as high as $10 per thousand. This showing has made the lumberman suddenly receptive to the forester's plea for the leaving of smaller trees, which before fell on deaf ears.

Other results are data permitting great improvement of log grading rules for the pine region, the revision of which is now under way by the Products personnel in cooperation with the Regional Logging Engineer; and for redwood, the initial development of log grades, which that region has never had; also, for the pine region, knowledge for the first time of the amount of manufacturing degrade of lumber and where it occurs. This item of manufacturing degrade the lumbermen, and even many Forest Service investigators in studies similar to these, outside of California, have taken at a lump figure assumed to be the same for all lumber grades produced. The fallacy and dangerous inaccuracy of this assumption are demonstrated by the studies made by this Station.

Among supplementary studies conducted by Products may be mentioned one of blue stain depreciation in the seasoning of California pine; and a study, in cooperation with the Regional Logging Engineer, the California office of the Bureau of Entomology and Plant Quarantine, and the Susanville lumbering operation of the Fruit Growers Supply Co., of the possibilities of economic salvage of beetle-killed pine timber. Both of these studies have contributed important knowledge.

A number of mimeographed progress reports on various phases of the studies have been issued for the prompt information of the Forest Service Region and the industry, and several trade journal articles published. The major writing task of Products is, however, the preparation and issuance of a Manual of Procedure for logging and sawmill studies of this kind, for which there is impatient demand by the engineers of the Western Pine Association and the more progressive operators who desire to carry on such studies for themselves. Preparation of this publication is an enormous job, complicated by frequent development of improvements in methods already used, as the work progresses, because of the uncrystallyzed state of this fast-growing technique, and aggravated by the unreliability of relief computing labor, which it has been necessary to use. Part I, on Field Procedure, has already been issued, in multilithed form. Part II, on Office Procedure, is more than half completed.

In summary of present project status, the Products Division of the Station has fairly adequate data applying to Site III Eastside timber, and operations in it using tractor-arch logging and railroad log transportation to large band mills. For the Westside pine region, data are mainly confined to Site I timber. In the redwood region, only one mill-production study (with corresponding logging study done by the Division of Redwood Management) has been made, in medium quality timber. There are no reliable data on redwood lumber depreciation. Studies are necessary in the timber site qualities for which data are now wanting, before anything convincing can be offered toward the promotion of selective logging, in the way of conclusive showing of financial returns, and with the applications desired by the Station to the possibility of improved silvicultural and management practices.

In spite of some hopeful signs, much of the private forestry picture is still dark. For example, the apparent encouragement for better silviculture, implied in the lumberman's reception of the Station's findings respecting the unprofitableness of cutting the smaller trees, is heavily counterbalanced by an increasing practice by the lumberman of

leaving all white fir uncut. While the leaving of this white fir gives a less desolate appearance to cut-over lands than did the old clear-cutting, the practice is dangerously deceptive, because it will result in deteriorating the forest of the next rotation, by giving it over increasingly to the low-value firs. Also, while the more intelligent large operators have accepted the evidence of the Station studies in respect to the comparative net returns from different sizes and species of trees, the majority apparently are unable to abandon the traditional notion that maximum realization per acre during the first cut is the most profitable practice. As long as this attitude prevails, nothing better can be expected on private lands than the leaving of submarginal trees, in spite of much talk about sustained yield on private operations. To obtain really constructive action on private lands by the lumberman, the heaviest ammunition is the profit showing which the Products logging and milling studies provide.

Other Activities

Statistics. For many years the Forest Service has cooperated with the Bureau of the Census in the field conduct of the annual census of lumber and timber products production. In the West this work is carried by the Products Divisions of the western Stations. Statistics of distribution and consumption are also compiled, as well as statistics of timber stands and other items.

Extension. A considerable amount of Products time is required by the requests coming in, by mail and personal call, for information in the whole Products field. In this, the Station acts as liaison agency for the Forest Products Laboratory and its results.